E & A

BEAN AND PEA WEEVILS

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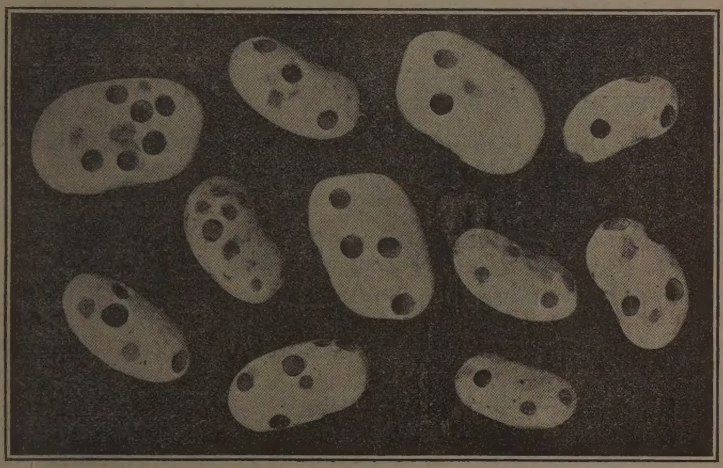

Work of the common bean weevil. Slightly enlarged.

FARMERS' BULLETIN 983
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BEANS, PEAS, AND COWPEAS are often damaged seriously in storage and in the field by weevils. Velvet beans and soy beans are rarely infested in this country. Bean and pea weevils not only destroy much of the Nation's food in the form of leguminous crops but are responsible for a curtailment in the acreage planted to these crops. They never attack corn and wheat.

There are no satisfactory artificial remedies that can be applied to kill weevil grubs in beans, peas, or cowpeas growing in the field.

The crop should be harvested as soon as possible after maturity and the seeds thrashed or shelled and treated by fumigation, heat, or cold storage, in order to kill the weevils in them before they can continue their destrucive work and mature.

The bean and cowpea weevils breed generation after generation in stored seeds. Hence seeds should be watched after treatment to make certain that they do not become reinfested. If stored in tight containers or in rooms free from adult weevils the chance of reinfestation will be reduced to a minimum.

This bulletin tells about the principal kinds of bean and pea weevils and explains fully the methods of averting losses from these pests.

BEAN AND PEA WEEVILS.

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THE SERIOUS LOSSES CAUSED BY BEAN AND PEA WEEVILS.

BEAN AND PEA WEEVILS are by no means new pests. They belong to a class of insects that cause a loss to farmers and merchants of many millions of dollars annually. One Province of Canada alone suffered from the ravages of the pea weevil to the extent of over $1,000,000 in a single year. It was estimated in 1902 that the acreage in field peas in Ontario would have been 1,000,000 instead of the actual 532,639 planted, had it not been for fear of the pea weevil. The bean weevil has been one of the chief factors in discouraging the production of field beans south of the latitude of New York, except in the higher altitudes. Few realize that the ravages of this weevil have forced farmers of many sections—as in the coastal regions of the Middle Atlantic States—to discontinue the production on a commercial scale of this valuable food crop and to turn their attention to other crops. The cowpea is now recognized as one of the most valuable cover crops for enriching the soil of the Southern States, and agriculturists claim that one of the drawbacks to its more general use for this purpose and for fodder is the susceptibility of cowpea seed to weevil attack. The cowpea weevils are the worst pests of cowpea seed. They are a big factor in maintaining, in years of normal production, the high cost of seed, and in the consequent curtailment of the use of this plant as a soil builder. These weevils,

also, because of the rapidity with which they destroy cowpeas grown for human consumption, have caused seedsmen and merchants to view with suspicion cowpeas grown in certain sections of the South, and this attitude has had a depressing effect upon the production of cowpeas for food. Yet the South is a veritable Eldorado for the production of leguminous crops for food once weevils are controlled. It is evident, therefore, that bean and pea weevils should be charged not only with the damage they cause leguminous foods actually produced but also with the indirect losses to the country due to the reduction in the areas planted to beans, peas, and cowpeas.

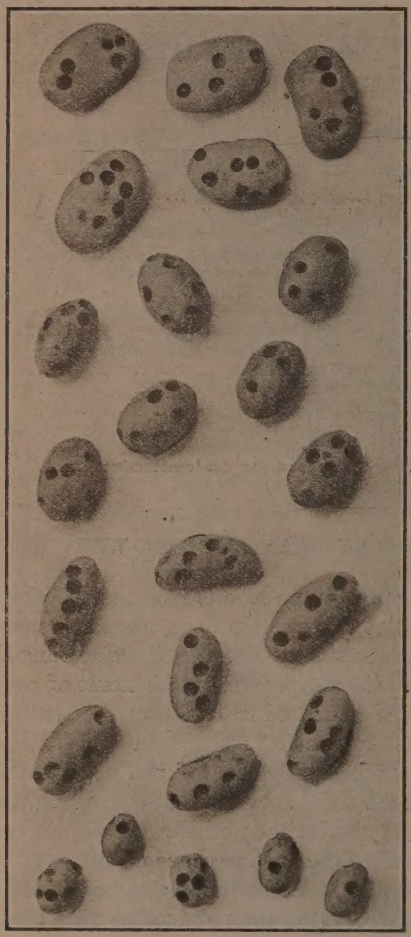

FIG. 1.—Types of navy beans showing the emergence holes of weevils. Each of these holes is made by a weevil as it has matured in the seed and left by cutting out a piece of the skin. All except the five small beans at the bottom have been injured by the common bean weevil. The five small beans were grown in Central America and are infested by the Mexican bean weevil. About natural size.

LOSSES OF LEGUMINOUS FOODS ESPECIALLY IMPORTANT NOW.

During times of peace losses caused by bean and pea weevils have been looked upon as a necessary evil to be accepted quietly or to be fought half-heartedly. The country has been so filled with stores of food that the destruction of a portion of them has been looked upon merely as a misfortune to the owner. Now, however, all this is changed, and such losses are seen to be contributory to a possible National disaster growing out of a shortage of food supplies.

While beans, peas, and cowpeas will always suffer from weevil attacks, unless an unanticipated cooperation among growers and merchants can be developed for the suppression of conditions favorable to weevil increase, there is no

reason why the great losses at present sustained in storage need be tolerated if those interested will inform themselves regarding the habits of these weevils and the methods for their control.

The Department of Agriculture, by the dissemination of information in reply to requests from all portions of the country, and by the actual supervision of public stores of these crops gathered to meet war needs, is doing all that it can to improve conditions. Cooperation with it in the protection of these foods from weevils has become a patriotic duty. Bean and pea weevils do not attack velvet beans and very seldom, in this country, the soy bean.

LOSSES OFTEN DISCOVERED TOO LATE.

Injury to edible legumes usually is observed first after the crop has been in storage for several months. Many believe that once the crop has been harvested it needs no further attention. Seeds put away at time of harvest are sometimes not examined again until the following planting season, when they are found "buggy"

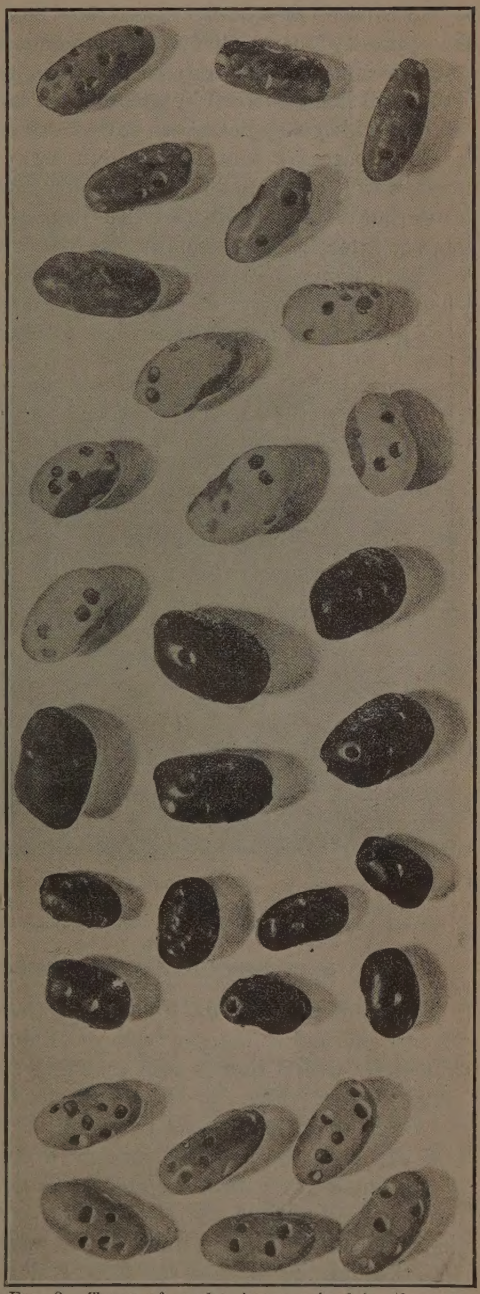

FIG. 2.—Types of garden beans ruined by the common bean weevil. No variety of bean is known to be free from attack. About natural size.

or "weevily" and badly damaged. The town or city war gardener has proudly put away for winter consumption beans grown during the previous summer, only to find them worthless as food and full of holes and honeycombed by grubs when later he has opened the jar or sack in which they have been stored. Wonder is often expressed that seeds apparently sound when put away for the winter, and kept always well covered, should be found later injured by weevils. Because small round holes (see title page and figs. 1 and 2) and weevils appear later in seeds seemingly perfect when harvested, a belief is current among many that bean and pea weevils develop spontaneously from the germ of the seed. That there is no foundation for such a belief is shown by the facts following.

FIG. 3.—Field peas in bloom. Adult pea weevils begin laying their eggs on the young pods in the field. It should be remembered that the bean and pea weevils begin their attack on the seed while the crop is developing in the field. Photo by Vinal.

HOW BEANS AND PEAS BECOME INFESTED.

Bean and pea weevils, like many other insect pests, pass through several marked changes in form and habits before reaching maturity. The adult weevil that is seen crawling about among the seeds is the parent insect. Many of these fly from the storage room or house to the fields where beans and peas (fig. 3) are growing. As the bean and pea pods develop, the mother weevil lays whitish eggs, either on the outside or within the pods. These eggs are so small that they are often not noticed, for they appear as mere white specks upon the pods. From these eggs there hatch white grubs that burrow their way through the pod into the soft developing beans or peas. Because these grubs are so very tiny, the holes through which they enter the

seeds are too small to be seen unless one searches for them with a microscope. Usually beans become infested first when they are nearly full grown. As seeds expand and harden in the final ripening process the holes in the skin through which the grubs entered become less and less easy to find. The wound in the skin either becomes entirely healed over or remains similar in appearance to a small pin prick.

Since beans and peas mature much faster than the weevil grubs within them, it happens that the weevil grubs are comparatively small or little developed, in many instances, when the crop is harvested and placed in storage. Thus many seeds that appear outwardly in excellent condition in reality have weevil grubs hidden away in their interior.

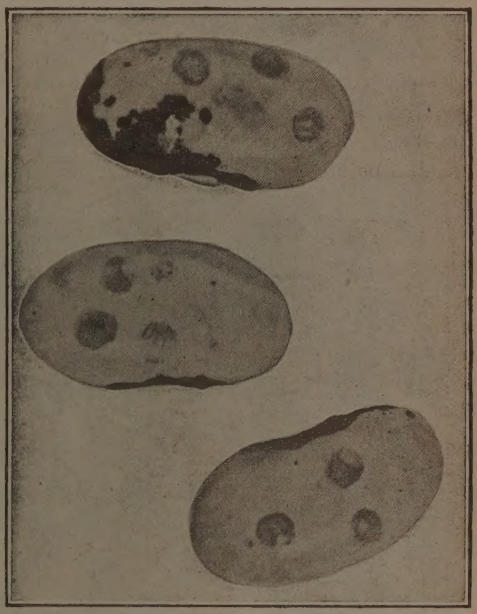

FIG. 4.—Three beans in which the common bean weevil grubs have become full grown and have eaten out from the interior of the bean to, but not puncturing, the skin. As they transform to the adult, each insect becomes dark colored and this dark color shows through the thin skin and makes the dark, sometimes bluish, translucent spots in beans. Such spots indicate that the seeds are infested. It should be remembered that while the grubs are still growing they are white in color, and the seeds do not indicate their presence by any such dark spots as shown above. Considerably enlarged.

WHERE WEEVILS IN STORAGE COME FROM.

At harvest time grubs developing from eggs laid on the pods in the field may have devoured very little of the seed contents, but if the seeds are stored in a warm place, or in a climate where the weather is sufficiently warm, they continue to feed and become well grown. When well grown they have eaten out of the seed contents a cavity somewhat larger than themselves and extending outward to, but not puncturing, the skin of the bean. (Fig. 4.) The grub then changes or transforms into the pupa (fig. 9, *c*; fig. 11, *c*) and later into the adult weevil. This adult has a pair of sharp jaws which it uses like a pair of scissors to cut out a circular flap (see fig. 5) in the bean skin, thus making the small round hole which is, to most gardeners, the first evidence that insects are in their beans.

Through these openings the adults crawl out and by their presence in sealed jars and other containers cause much concern.

DESTRUCTION CONTINUES IN STORAGE.

With the exception of the pea weevil that attacks the different varieties of peas, the broad or Windsor bean weevil, and the lentil weevil, the weevils attacking beans and cowpeas continue to produce generation after generation in dried seeds in storage. (Fig. 6.) The pea and the broad-bean weevils will die in storage and can not reproduce unless they can find growing plants in which to lay eggs. But the ordinary bean and cowpea weevils lay eggs for

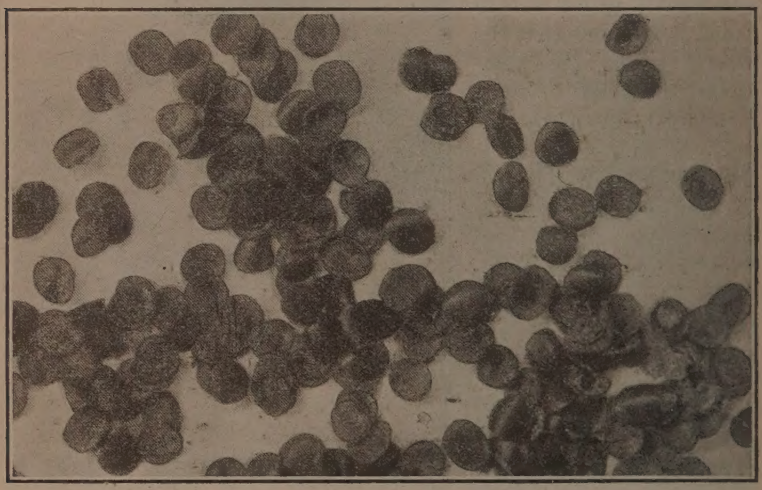

FIG. 5.—In escaping from beans, peas, or cowpeas, or any host, the weevils leave behind them the small round holes familiar to all. In making these holes they use their jaws to cut around the dark spots shown in figure 4 and then push away the circular flap of skin just as one opens a tin can of preserved fruit with a can opener. These circular bits of skin, shown above, about 4 times natural size, may be found among the seeds.

successive generations as readily upon dried seeds in storage as upon the growing plants in the field. As each generation of weevils reduces the value of seeds for planting and for food, steps should be taken to kill, at harvest time, such grubs as may be in the seeds and thus prevent further losses. If this is not done the seeds become honeycombed by the feeding of generations of grubs and may be reduced to a powder. (Fig. 7.)

THERE ARE DIFFERENT KINDS OF WEEVILS.

Injury to leguminous crops is caused by more than one insect. Those considered in this bulletin are the pea weevil,[1] the common bean weevil,[2] the cowpea weevil,[3] the four-spotted bean weevil,[4] the

[1] *Bruchus pisorum* Linnaeus.
[2] *B. obtectus* Say.
[3] *B. chinensis* Linnaeus.
[4] *B. quadrimaculatus* Fabricius.

broad-bean weevil,[1] the lentil weevil,[2] and the Mexican bean weevil.[3] These are all commonly found in supplies of beans, peas, cowpeas, or

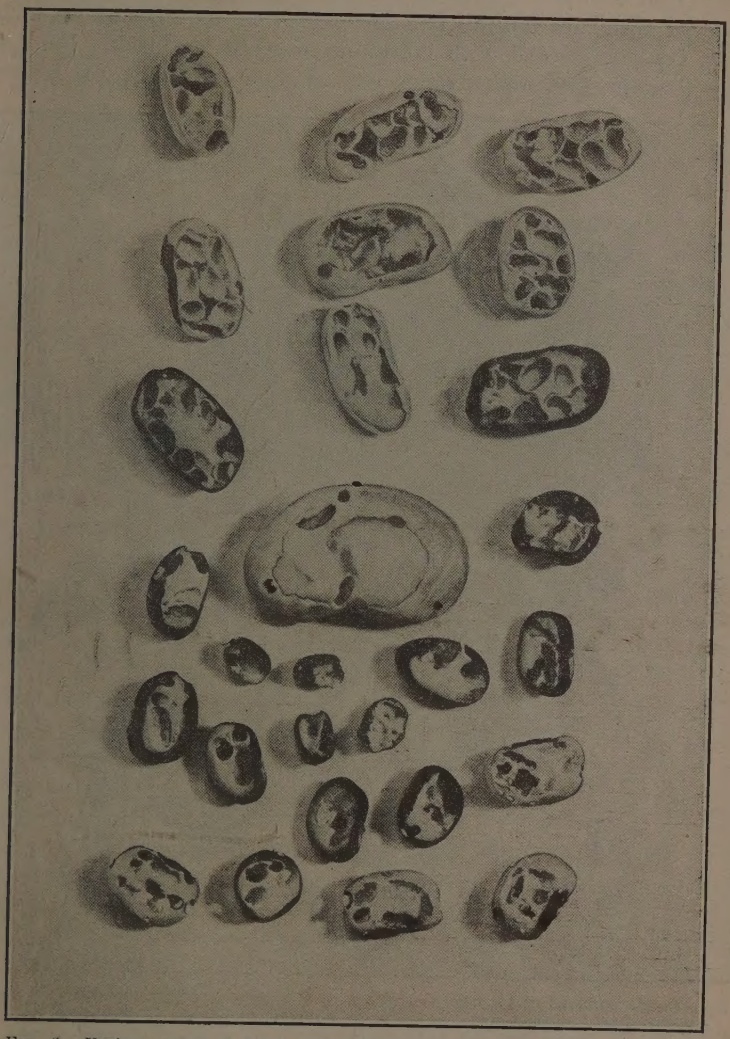

FIG. 6.—Various types of beans and cowpeas cut lengthwise to show how severely they may be damaged by bean and cowpea weevil grubs. Such beans and cowpeas are not fit for human food. Slightly enlarged.

lentils in this country. Other species are sometimes found in imported seeds, but will not be discussed here.

[1] *Bruchus rufimanus* Boheman. [2] *B. lentis* Boheman. [3] *Spermophagus pectoralis* Say.

GENERAL DESCRIPTIVE FACTS.

The bean and pea weevils of the United States are all very small. None of them are longer than one-eighth to one-fifth of an inch. They are dull-colored with markings of white or black. For the general shape, size, and arrangement of these markings, see figures

FIG. 7.—Leguminous crops may be reduced to a powder by the continued feeding of weevil grubs. In the bottom of sacks or boxes in which weevily beans or cowpeas are held for a long time one finds quantities of dead weevils and the powdered remains of the seeds such as are shown above. About natural size.

9, 11, 12, 14, 17, and 18. Their eggs are from one-fiftieth to one-twenty-fifth of an inch long, white or whitish, and appear as specks (see figs. 8 and 13) when laid on beans and cowpeas in storage.

The larvæ, or grubs, naturally are very small when first hatched and are white in color. After feeding they become somewhat mag-

gotlike in general appearance, being nearly cylindrical, fleshy, distinctly wrinkled, more or less curved in outline, and not more than one-fourth of an inch long and usually less.

By the time the grub has become full grown it has eaten out in the seed contents a cell in which to transform to the pupa or chrysalis. Before transforming it secretes a substance which hardens into a white, filmy cell about itself, and this serves to protect the helpless pupa while the changes to the adult are taking place. For the general shape and appearance of the grub and pupa, see figures 9, 11, and 14, *b* and *c*, and figure 12, *c*. The pupal cells are shown in figure 21.

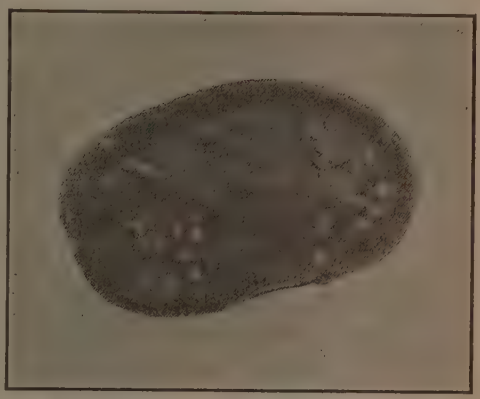

FIG. 8.—A cowpea seed showing the eggs of a cowpea weevil. The eggs of bean and pea weevils vary in shape, but they are always small, ranging in size from one-fiftieth to one twenty-fifth of an inch long. They are white or whitish in color, and may be laid anywhere upon the outside of the seed, as indicated here, or in the cavities in the seed made by a previous generation of grubs, or on the sides of containers such as burlap sacks, barrels, etc. The eggs can be distinctly seen on seeds; they appear as tiny white specks. Much enlarged.

THE PEA WEEVIL.[1]

The pea weevil is the most serious enemy of the field or garden pea. It now occurs over almost the entire globe wherever peas are cultivated. It is scarcely known, however, in the colder countries of northern Europe and does comparatively little damage for the most part in the coldest parts of Canada and the United States. Continuous cropping of land to peas naturally leads to a constant increase in the number of pea weevils, as evidenced by the fact that garden peas grown almost anywhere in the United States, except in places in our more northern States or in high altitudes, are apt to be badly affected. This pest was causing serious damage to garden peas in Pennsylvania, New Jersey, and southern New York as early as 1748.

The pea weevil is a small grayish or brownish-gray beetle about a fifth of an inch long and marked with black and white spots as shown in figure 9. The short line to the right of *a* in the illustration gives the actual length of the adult beetle. The adults appear on the vines when the peas come into bloom and deposit their eggs singly upon the

[1] *Bruchus pisorum* Linnaeus.

surface of the pods, to which they attach them with a peculiar viscid secretion, which turns white upon drying. The length of time required for the eggs to hatch and for the grub or larva to mature into the adult of the next generation varies with the climate. In the District of Columbia adults have appeared as early as July 21. Others have been reared as late as the middle of August. A very considerable portion of the beetles mature and leave the seeds in the latter part of the summer in the latitude of Washington, D. C., but farther north and in higher altitudes the adults remain in the peas until the following spring, when they emerge in storage or are planted with the seed. It is in the adult stage that the weevil passes the winter, hibernating either in secluded spots in fields or buildings or in the pea seed itself. *The pea weevil has only one generation a year and can not reproduce in dried peas.* Usually only one insect develops in a single seed (see fig. 10).

FIG. 9.—The pea weevil: *a*, The adult beetle; *b*, its larva or grub; *c*, its pupa. The line to the right of the adult (*a*) represents the actual length of the beetle, and the size of the larva and pupa are in proportion. (Chittenden.)

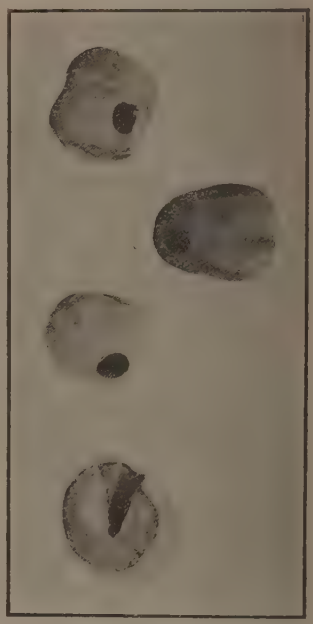

FIG. 10.—Four garden peas showing the exit hole of the pea weevil. Note that only one pea weevil develops in a single pea. One seed has been sectioned to show the cavity made by the grub. Enlarged.

THE COMMON BEAN WEEVIL.[1]

The common bean weevil is the most formidable enemy to the culture of beans in the United States as well as in many other countries. It occurs in nearly every State of the Union and is generally distributed throughout Mexico, Central America, and South America. It has been found in beans imported from southern Europe, Persia, India, China, Algeria, South Africa, Madeira, the Azores, and the Canary Islands. Commerce has carried it to all the larger markets

[1] *Bruchus obtectus* Say.

of the world. So severe is its attack in the warmer sections of this country that dried beans for seed and for food are grown mostly in the more northern States and California. In the coastal region of the Middle Atlantic States and farther south bean growing is made very difficult, if not rendered unprofitable, by the unmolested increase of the bean weevil.

The bean weevil is smaller than the pea weevil, being only about an eighth of an inch long, and shaped and marked as illustrated in figure 11. The adult beetle is so coated with fine hairs that it appears brownish gray or olive color. Unlike the pea weevil, the bean weevil not only can develop in growing beans in the field but also can breed generation after generation in dried beans in storage. As many as 28 weevil grubs have been found in a single bean.

Experiments have demonstrated that the eggs of the bean weevil require from 5 days in the hottest weather to 20 days at a cooler

FIG. 11.—The common bean weevil: *a*, The adult beetle; *b*, the larva or grub; *c*, the pupa. The short line to right of adult beetle (*a*) represents its real length. (Chittenden.)

temperature to hatch, and that the larvæ or grubs become full grown in from 11 to 42 days and the pupæ in from 5 to 18 days, according to the temperature. It requires 21 to 80 days at least, according to the season and locality, for a generation of the bean weevil to develop. In the District of Columbia there may be as many as six generations a year. The warmer the climate the greater the number of generations and the consequent damage done by the weevil grubs.

In a climate similar to that of the District of Columbia and adjacent parts of Maryland and Virginia adults of the first generation started in the field begin to emerge as early as October. If the fall is early and the seeds are stored in a cold place no adults may emerge before the following spring. If seeds are stored in a warm place adults may emerge at any time during the winter months. After emergence in storage the adult female lay eggs either on the beans or on the sides of the receptacles in which the seeds are stored.

THE COWPEA WEEVIL.[1]

The cowpea weevil (fig. 12) is a foreign species first described from China but now widely distributed in dried seeds over the entire United States. Among the places from which it has been recorded may be mentioned China, Japan, and the East Indies in Asia; Egypt, Sierra Leone, Barbary Coast, Algeria, and the Cape of Good Hope in Africa; Porto Rico, Cuba, Mexico, Panama,

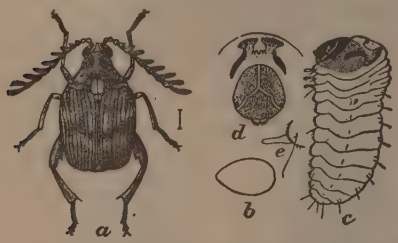

FIG. 12.—The cowpea weevil: *a*, Adult male; *b*, egg; *c*, postembryonic larva; *d*, front view of head of same; *e*, thoracic leg of same. *a*, Much enlarged; *b*, *c*, more enlarged. (Chittenden.)

Brazil, and Chile. Although it prefers cowpeas (see fig. 13) and is the worst pest that the cowpea has, it frequently attacks the common pea, pigeon pea, lentil, chick pea, mung bean, and common white bean.

The adult weevil is about an eighth of an inch long and may be distinguished from weevils discussed in this bulletin by the elevated ivory-like spots near the middle of the body, as shown in figure 12.

Like the bean weevil, the cowpea weevil breeds generation after generation in stored cowpeas and often reduces them to a powder. Because of the very warm weather of the Southern States, where the cowpea weevil is most severe in its attack

FIG. 13.—Different varieties of cowpeas showing infestation by the cowpea weevil. Seed about natural size; the white specks on the seeds are the eggs of the cowpea weevil.

[1] *Bruchus chinensis* Linnæus.

upon cowpeas, the grubs mature very fast and often the adults may emerge as soon as the crop is ripe. In a fairly warm or indoor temperature six to seven generations may mature annually in a climate like that of Washington, D. C.

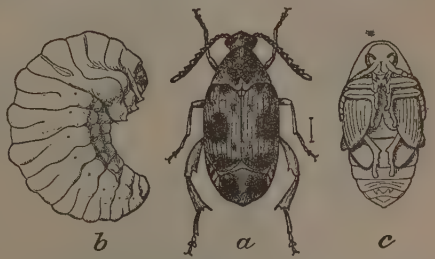

FIG. 14.—The four-spotted bean weevil: *a*, Adult weevil; *b*, larva or grub; *c*, pupa. Enlarged. (Chittenden.)

THE FOUR-SPOTTED BEAN WEEVIL.[1]

The four-spotted bean weevil somewhat resembles and is a trifle larger than the cowpea weevil, but may be distinguished from it not only by its more slender body but by the four black spots upon its wing covers as shown in figure 14.

FIG. 15.—Chick peas affected by the four-spotted bean weevil. Compare these with the two sectioned chick peas at the bottom of figure 21. Enlarged.

In 1885 this species was found to be swarming on black-eyed peas from Texas exhibited at the Atlanta Cotton Exposition. Since then it has been found attacking cowpeas throughout the Southern States and as far north as Iowa and is probably present wherever cowpeas are grown. The cowpea is its favorite host food, although peas and beans of many varieties are attacked (see fig. 15).

The life history of the four-spotted bean weevil is practically the same as that of the cowpea weevil.

THE LENTIL WEEVIL.[2]

The lentil weevil is not known to be established in this country at the present time, although it has been found repeatedly in imported lentils from Europe. It is a pest of the lentil crop in middle and southern Europe, Egypt, and Syria. While lentil

[1] *Bruchus quadrimaculatus* Fabricius. [2] *B. lentis* Boheman.

growing is on the increase in this country, it is hoped to keep this pest from becoming established in North America.

FIG. 16.—Lentils of two varieties showing injury by the lentil weevil. While only one lentil weevil matures in a single seed, it is capable of practically destroying that seed, as indicated by the sectioned seeds at the bottom of the illustration. Somewhat enlarged.

The lentil weevil, only one of which matures in a single seed, resembles somewhat the pea weevil but is only about an eighth of an inch long. Like the pea and broad-bean weevils, it has but one generation a year. Lentils showing the emergence holes and injury caused by this weevil are shown in figure 16.

FIG. 17.—The Mexican bean weevil: Adult weevil with line to left indicating its actual length. Infested bean to left showing two emergence holes and six eggs. (Chittenden.)

THE MEXICAN BEAN WEEVIL.[1]

The Mexican bean weevil is an inhabitant of South and Central America and is frequently found at our Pacific and Atlantic ports, infesting beans imported from these countries. It attacks beans and cowpeas. It breeds continuously in dried seeds and is capable of being as injurious as the common bean weevil, as indicated by the five small beans affected by this pest, shown at the bottom of figure 1. For the size, shape, and coloration of this insect, see figure 17.

[1] *Spermophagus pectoralis* Say.

THE BROAD-BEAN WEEVIL.[1]

The broad-bean weevil (fig. 18), sometimes called the European bean weevil, is common and destructive in Europe and North Africa. While it feeds upon various sorts of beans and peas, it appears to prefer the broad or Windsor beans (see figs. 19–20). Although it has been found from Canada to Texas in Windsor beans imported into various parts of

FIG. 18.—Adult of the broad-bean weevil. Greatly enlarged. (Chittenden.)

this country, the first discovery of its definite establishment in the United States was made in 1909 at San Luis Obispo, Cal., where it was injuring the broad or horse bean (*Vicia faba*) grown for stock feed. Practically every bean of this variety entering the warehouses of New York is more or less damaged by this pest.

[1] *Bruchus rufimanus* Boheman.

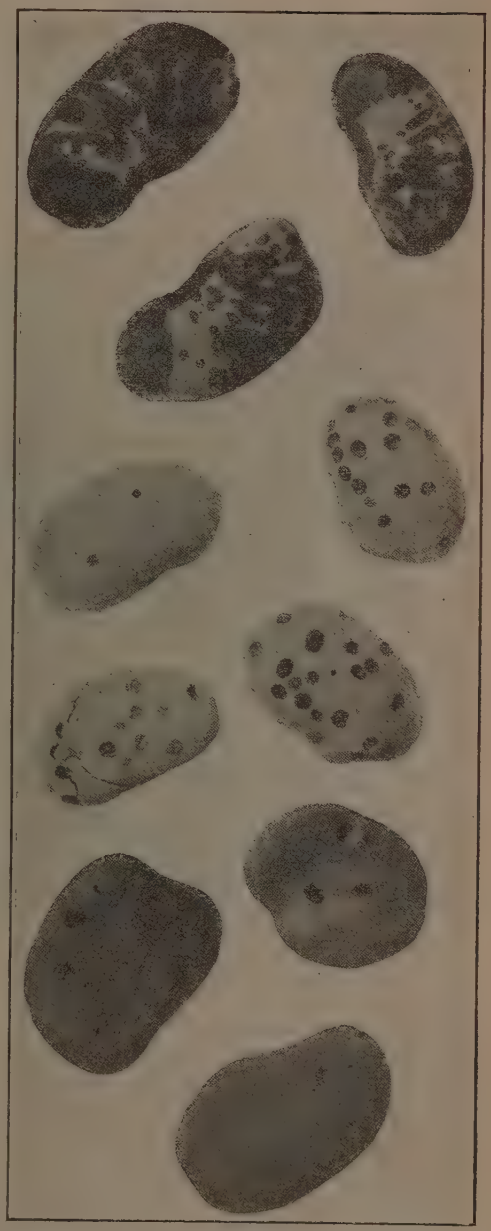

FIG. 19.—Brazilian beans (above) and lima beans (center) infested by the common bean weevil. Lima beans are not so often infested as common garden beans. The three broad or Windsor beans at the bottom show infestation by the broad-bean weevil. Somewhat enlarged.

The broad-bean weevil closely resembles the common pea weevil, being about the same size, one-fifth of an inch long, and of similar appearance. It can, however, be readily distinguished by its much narrower thorax and fainter markings, as a comparison of figures 18 and 9 will show.

WHY WEEVILS LIMIT ACREAGE PLANTED TO CERTAIN LEGUMINOUS FOOD CROPS.

It has been pointed out already that infestation nearly always takes place in the field while the crop is maturing. With garden or Canadian peas, lentils, and broad or Windsor beans infested with the pea weevil, the lentil weevil, and the broad-bean weevil, respectively, this is always the case, for these weevils never breed in dried seeds. It is generally known that the colder the winters the shorter the

FIG. 20.—A broad, horse, or Windsor bean, grown in California, cut open to show the damage caused by the grubs of the broad-bean weevil. Only one generation of this weevil occurs each year. As each cavity represents the feeding of one grub, this bean is badly affected. Considerably enlarged.

growing season and the fewer the bean and pea weevils that survive the cold of winter and are ready to fly to the fields to start the infestation of the growing crop by laying eggs upon the pods. The farther south one goes the more mild the winters become, the longer the growing season, and the greater the number of weevils that can live through the winter.

As far south as the District of Columbia and the adjacent tidewater country of adjoining States, therefore, overwintering weevils attack the beans and peas in large numbers and succeed in years favorable for them in laying so many eggs upon the pods that each

developing bean becomes affected and often may support as many as 20 to 28 weevil grubs. Because of the long, warm falls and the length of time the plants are allowed to remain in the field after the crop has ripened, either standing in the ground or pulled and stacked, these grubs are given every opportunity to develop into adults or at least to become very well grown in an unusually large number of cases, and therefore they cause greater damage than do weevils in bean fields farther north. Thus beans grown in latitudes south of New York City, except in higher altitudes, as in the mountainous regions of the Alleghenies, become more universally infested than those grown north of that latitude. As weevils in beans are not killed so easily as are many insects, and as their presence in numbers in beans is objectionable whether beans are grown for food or for planting, even when the grubs have been killed (see fig. 21), the growing of beans on a commercial scale for dried seed has been given up in our more southern latitudes. This explains the question often asked why beans and peas grown in portions of the States of California, Michigan, New York, Washington, Oregon, or Idaho, or even in Canada, find their way into our southern markets, which one would expect should be supplied by southern-grown beans and peas. Practically all the dried beans grown for seed and for food are grown in these northern States where the bean weevils are not able, because of climatic checks, to cause so much damage. Of course weevils do not affect the growing beans to be eaten green, as "string beans" or green shelled beans, for such beans are not, at the time of gathering, infested; or if infested, the grubs are too small to interfere with their value as food.

FIG. 21.—Beans (six upper seeds) and chick peas (two lower seeds). The skin of the beans has been removed to reveal the cavities eaten out by the common bean weevil grubs. The grubs have been killed by fumigation and have turned black. Note the white paper-like cell or cocoon about each of the grubs. The chick peas have been cut open to show how the larvæ of the four-spotted bean weevil can burrow to the very center of the seed. Slightly enlarged.

GERMINATION AFFECTED BY WEEVIL ATTACK.

Unless beans, peas, and cowpeas are very badly infested with weevils the so-called germ of the seed is seldom itself affected.

Beans as badly infested as those shown in figures 1, 6, and 22 are worthless for planting. As the young bean or pea plant depends upon the food stored in the seed to give it its first start, the destruction of any portion of the seed by weevils lessens by so much the vigor of the plant. In one experiment on record, only 50 per cent of infested beans germinated, and of these 30 per cent were so badly injured that they could not develop into normal plants. The smaller the seed, the greater proportional damage a single weevil grub can cause. Often one grub may ruin a small cowpea seed (see fig. 13) or a lentil (see fig. 16), whereas it would not so seriously affect a large seed like the lima bean.

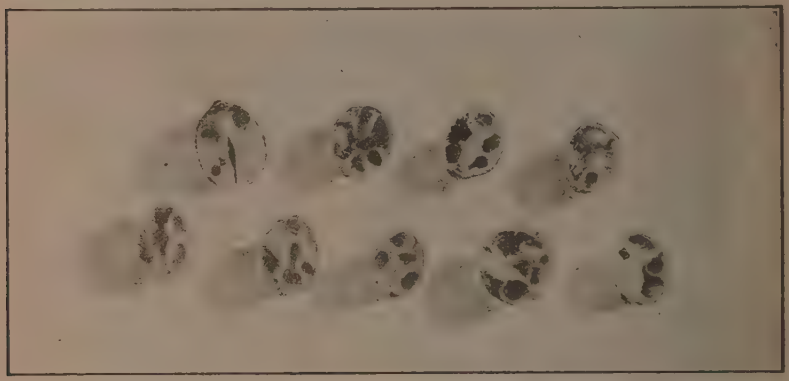

FIG. 22.—Nine navy beans cut crosswise to prove how the common bean weevil can ruin seeds for eating or planting. About natural size.

REMEDIES.

There are a number of remedies that may be applied to lessen the abundance of weevils and to prevent them from causing injury or damage in storage. Any remedy that lessens the number of weevils present in the field has a direct effect upon the number of weevils to be fought in storage, and vice versa.

PLANT ONLY SEEDS FREE FROM INFESTATION.

If seeds are planted that contain weevils, the adult weevils emerge from the seed after it has been planted and live in the field until the pods are sufficiently developed to receive the weevil eggs. They add their numbers to those in the field that have migrated from the place of seed storage. To plant peas, beans, and cowpeas containing living weevils only invites a "buggy" crop. Since the pea and broad-bean weevils can not breed in dried seeds, peas intended for planting may be held over for one year in tight paper bags so that the weevils that

emerge can not live but will die before the second spring. Beans and cowpeas affected by other weevils should be treated.

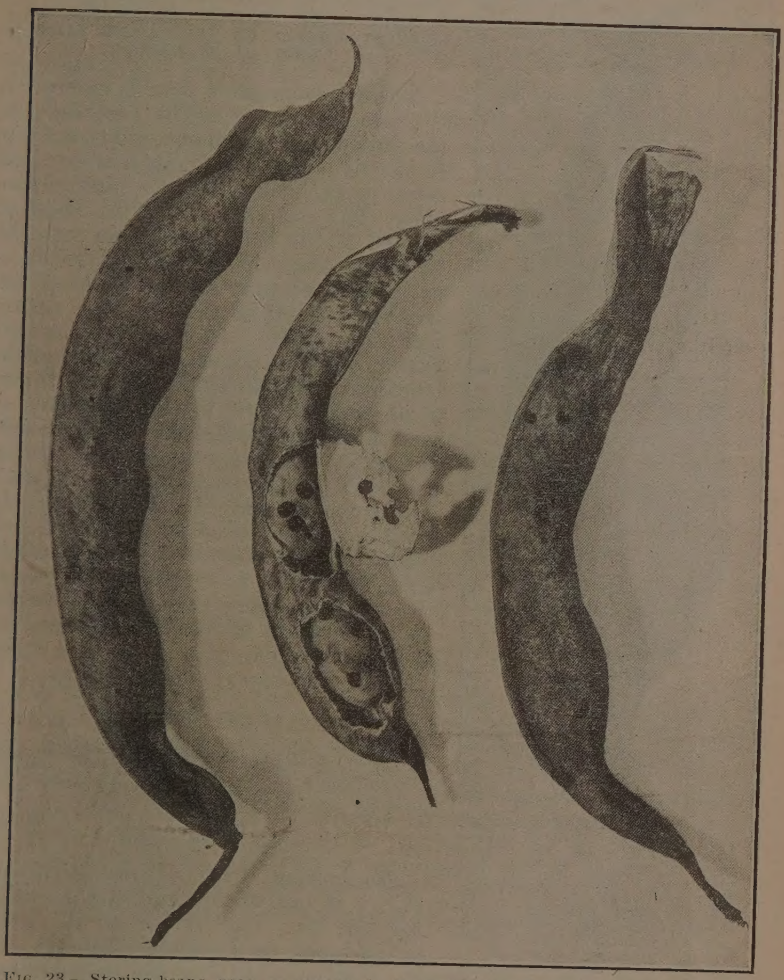

FIG. 23.—Storing beans, peas, or cowpeas in the pod will not prevent the weevils from ruining the beans if they are already in the seeds. Neither will it prevent them from emerging, as indicated by the holes they have made in the pods shown above in making their escape from the seeds. One pod has been cut to expose the infested beans within. Work of the common bean weevil. Enlarged.

PRACTICE CLEAN CULTURE.

In gathering the crop exercise care to leave no portion of it in the field. Seeds scattered on the ground or left in scattered pods on the dried vines can carry the pest over winter and furnish a supply of

FIG. 24.—Pod of field pea showing the exit hole of the cowpea weevil. This pod was taken from a bale of field-pea hay grown in Florida and indicates that even field-pea hay grown only for cattle food may be instrumental in offsetting community cooperation to lessen weevil injury. Somewhat enlarged.

weevils the following summer to offset the trouble taken to kill the weevils in storage and in seeds for planting.

HARVEST, THRASH OR SHELL, AND SACK AS SOON AS POSSIBLE.

Because some adult weevils emerge in the late summer and fall, according to the latitude, leguminous crops subject to weevil attack should be harvested as soon as possible after reaching maturity. The seed should be thrashed or shelled at the earliest possible moment in order that the seeds may be more easily and cheaply treated to keep the weevil grubs from feeding and maturing into adults. Storing in the pod does not confine the weevils. The grubs continue their development and transform to the adult in the unshelled as well as in the shelled seeds. Adult weevils can gnaw their way out of dried pods, as shown by the exit holes in the pods of figures 23 and 24. The weevils in large bulks of unthrashed or unshelled beans or peas can not be satisfactorily treated. There is only one answer to the often-asked question, "Is it better to store beans or peas in the pod or shelled?" Shell the seeds and treat them if you expect weevil injury.

FUMIGATION.

Weevils may be killed in storage by fumigation with carbon disulphid or carbon tetrachlorid.

CARBON DISULPHID.

Fumigation with carbon disulphid (CS_2) is one of the simplest remedies for weevils. Use of carbon disulphid is discussed in Farmers' Bulletin 799, which can be had upon request. Carbon disulphid can be purchased at any drug store or from any dealer in chemical supplies. It is a liquid sold by the pound in tin cans of varying size. Upon exposure to the air it vaporizes into a gas that is heavier than air and of such a disagreeable odor that its presence always attracts attention. It is much like gasoline in that its vapor will explode if fire in any form is brought near it. It is, however, an excellent and standard fumigant, and, if used with a full knowledge of its properties as explained in Farmers' Bulletin 799 and with the same precautions given gasoline, is safe and will give good results.

Seeds to be fumigated should be placed in an air-tight container. This may be a tin pail, wash boiler, barrel, galvanized iron garbage

can, or other receptacle, or a specially constructed fumigation box or room, according to the amount of seed to be fumigated. One of the simplest satisfactory containers for fumigation on a small scale is a water-tight barrel. The tighter the receptacle, the better the results. Satisfactory results can not be secured if fumigation is attempted in a room full of cracks.

Carbon disulphid should be used at the rate of from 3 to 8 pounds to each 1,000 cubic feet of space to be fumigated, the amount to be used varying with the tightness of the container and the temperature. The liquid should be poured over the top of the seeds to be fumigated. It quickly vaporizes and as the gas is heavier than air, it sinks to the very bottom of the container, filling all the air spaces. Fumigation should continue for from 24 to 48 hours.

Beans, cowpeas, and peas can be stored and fumigated conveniently in water-tight barrels. These should be filled to within a few inches of the top with seeds. In fumigating, pour one-half cup of carbon disulphid on the seeds and then cover the top of the barrel with a double thickness of heavy wrapping paper tied tight around the top. A wooden cover will also be useful in keeping in the fumes.

Fumigation with carbon disulphid to give the best results should be carried on at or above a temperature of 75° F. It is not effective at temperatures below 60° F. After fumigation the seeds should be examined occasionally and given a second or third fumigation should living weevils be found.

Carbon disulphid costs from 8 to 25 cents per pound, according to the amount purchased. If used according to directions, it will not injure thoroughly dry seeds for planting. Its disagreeable odor passes away after seeds fumigated have been aired and in no way affects them for eating purposes.

CARBON TETRACHLORID.

Carbon tetrachlorid (CCl_4) is a fumigant that has been used as a substitute for carbon disulphid in fumigation work, since it has the advantage over carbon disulphid of being noninflammable. When pure, carbon tetrachlorid is a thin, transparent, colorless, oily liquid, with a pungent, aromatic odor. Except for being noninflammable, it is similar to carbon disulphid in all essential features, from the standpoint of application. At the rate of 28 cents a pound it costs fully three or four times as much as carbon disulphid, however, and when used at the same rate is considered about one-half as effective. Its great advantage is its noninflammability.

HEAT.

Heat as a means of killing weevils in legumes is growing in favor. Small quantities of seed grown on the farm or in the town garden can be treated by placing them in an oven and heating them to 120° to 145° F. for several hours. An old remedy is to dip seeds into boiling water for one minute. Holding seed in boiling water for more than one minute will injure their value for planting purposes. On removal they should be immediately spread out and dried rapidly.

Weevil development in large quantities of beans, peas, and cowpeas can be stopped by a process known as kiln-drying. This process consists in heating the seeds to a temperature of 120° to 145° F. while they are being passed through a machine called a drier. This treat-

ment not only removes a large portion of the moisture in the seeds but also kills all insects in them.

The embryos of the bean weevil are killed when exposed to 125.6° F. for 10 minutes; the newly hatched larvæ die in 7 minutes at 131° F.; full grown larvæ in beans die in 20 minutes at 131° F.; and pupæ die in beans when exposed for 25 minutes at 131° F. Adults are killed by a 4-minute exposure to 131° F. These data can not be relied upon when large masses of seed are to be treated. The investigator who obtained them found that 9 hours were required for the center of 2 quarts of beans inclosed in a tight paper bag to reach the surrounding temperature of 131° F. As is done in kiln-drying, the seeds should be spread out in order that all may be affected quickly and uniformly by the heat. When thus spread out an exposure to 131° F. for 1 hour should be sufficient.

COLD AND COLD STORAGE.

Weevils will not feed and cause damage at low temperatures. It is not known at what temperature development ceases but probably little or no development takes place at or below 50° F. Cowpeas can be kept free from weevils if held in storage at a temperature of 32° to 34° F. It is claimed that exposure for a season at this temperature, at a cost of 15 to 25 cents per bushel for the season, does not affect the germinating power of the seed. The storage room should be kept as dry as possible and the seeds should be handled in sacks as in warehouses. It is interesting to note that cowpeas held for a season at 32° to 34° F. were found to lose their germinating power no sooner on removal to normal temperatures than cowpeas not thus exposed to cold.

LIME OR DUST AS PROTECTION TO SEED.

In the Southern States, where weevils cause so great injury to stored seeds, certain farmers have resorted to mixing their seed cowpeas with dry road dust or air-slaked lime. Tests prove that the storage of cowpeas with air-slaked lime at the rate of 1 part by weight of lime to 2 parts of peas is a great help in protecting seeds held for planting. The dust or lime does not kill the weevil grubs developing in the seeds if these are already in the seeds at harvest time, but it either prevents adult weevils from emerging or, if they succeed in emerging, from laying their eggs on the seeds for successive generations. The dust or lime, in other words, prevents continued breeding in storage. Either substance would probably be a nuisance if mixed with cowpeas intended for food, as the lime or dust would work into the emergence holes and be difficult to remove.

TREATMENT DOES NOT PREVENT REINFESTATION.

Treatment of legumes subject to infestation by weevils that can breed generation after generation in storage will not keep them free from weevils if they are stored so that adult weevils can get to them and lay eggs on them. The application of remedial measures may kill all weevils in the seed at the time of treatment, but it should be remembered that no treatment has a lasting effect in preventing reinfestation from outside sources. Seeds once treated should be stored in rooms free from adult weevils, or placed in tight barrels or sacks made of closely woven material, and should be examined occasionally as a guard against subsequent infestation.

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